JPL

Background image

NASA's Search for Exoplanets and Life in the Universe

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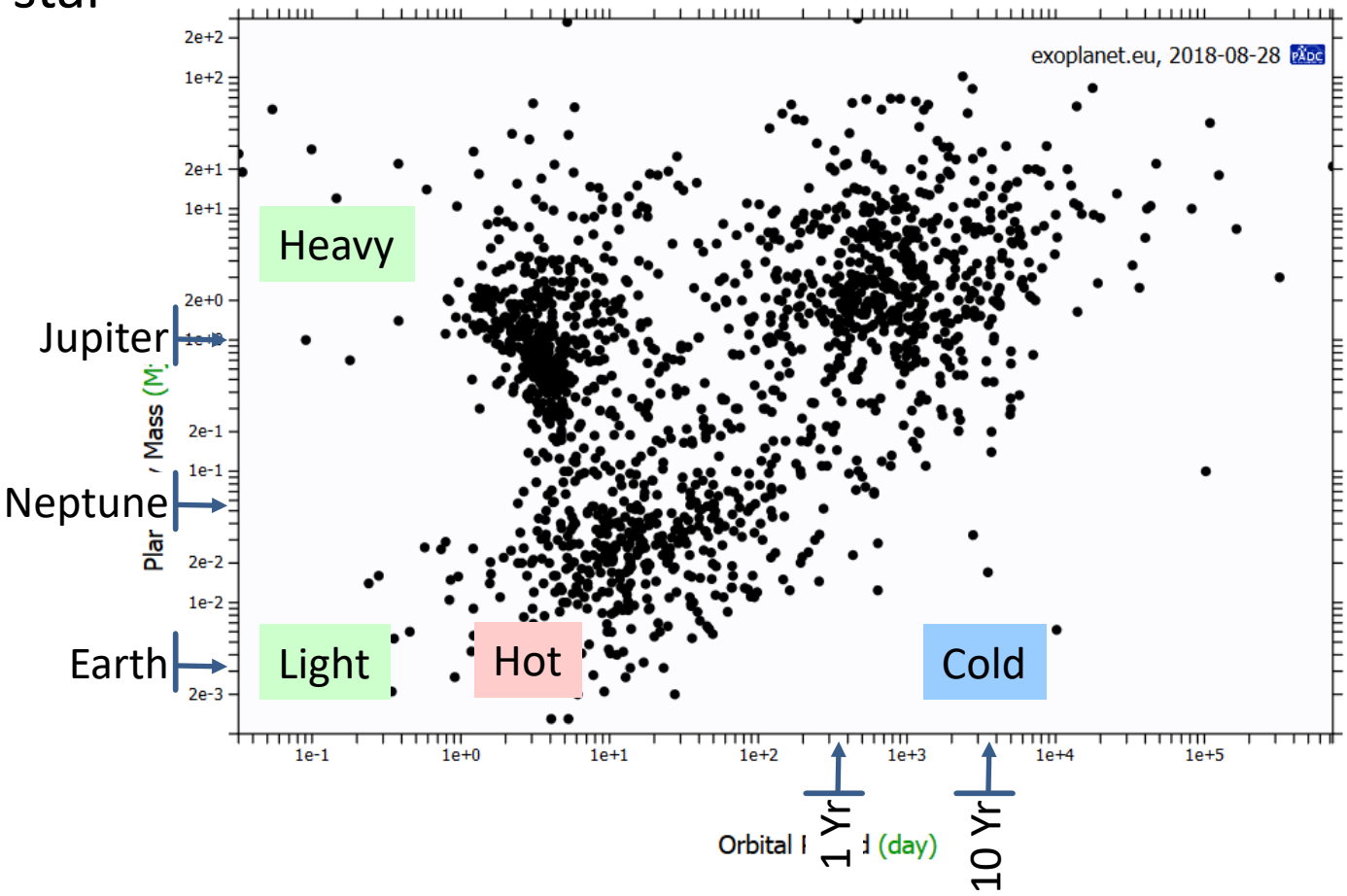
Understanding Our Place in the Universe

- Exoplanets are planets around nearby stars
- One of Humankind's oldest questions: Are We Alone?
- In this generation we could begin to answer that
  - ~~Are we alone?~~ → How crowded is our neighborhood?
- How common are exoplanets?
  - How common are habitable exoplanets? (Real Estate)
  - How common are inhabited exoplanets? (Forests and wine)
  - How common is intelligent life? (Chess club)
- How close are our nearest neighbors?

Exoplanets are VERY common

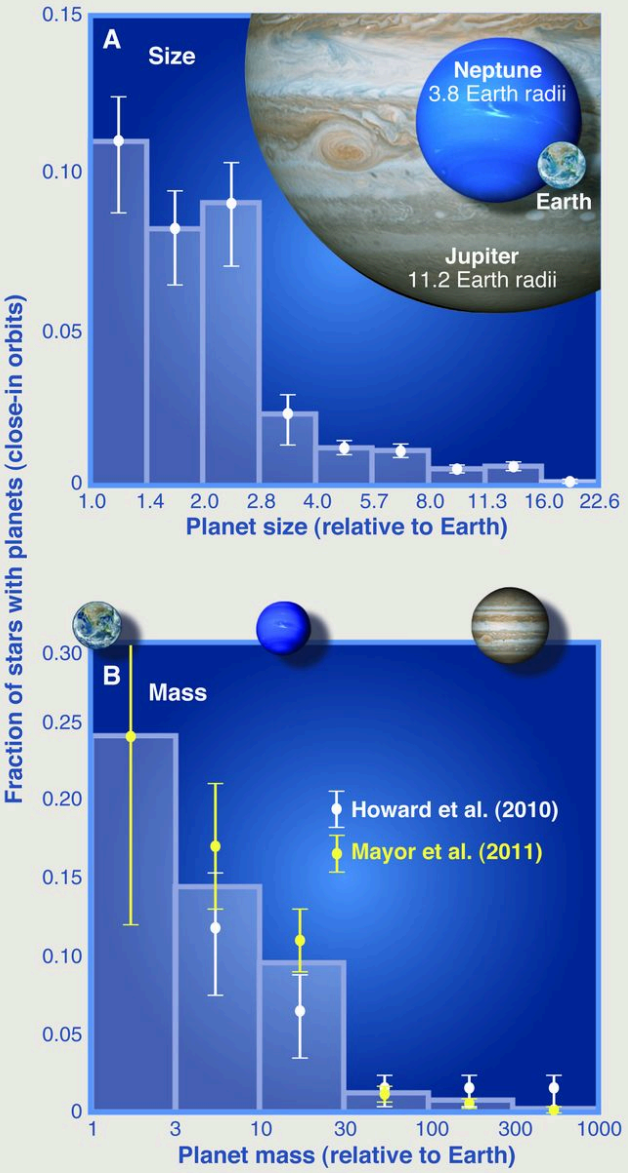
- Hot, Cold
- Big and heavy, Small and light
- Fluffy, Wet, Rocky, Molten
- Bright star, dim star



Medium-Small Exoplanets are the Most Common

- Large exoplanets are easier to detect than small, but small exoplanets are distinctly more common than large
- This emphasis extends to Neptune-size planets, a few times larger than Earth

- As exoplanet detection methods become more sensitive, we will find more planets in the known exoplanet systems

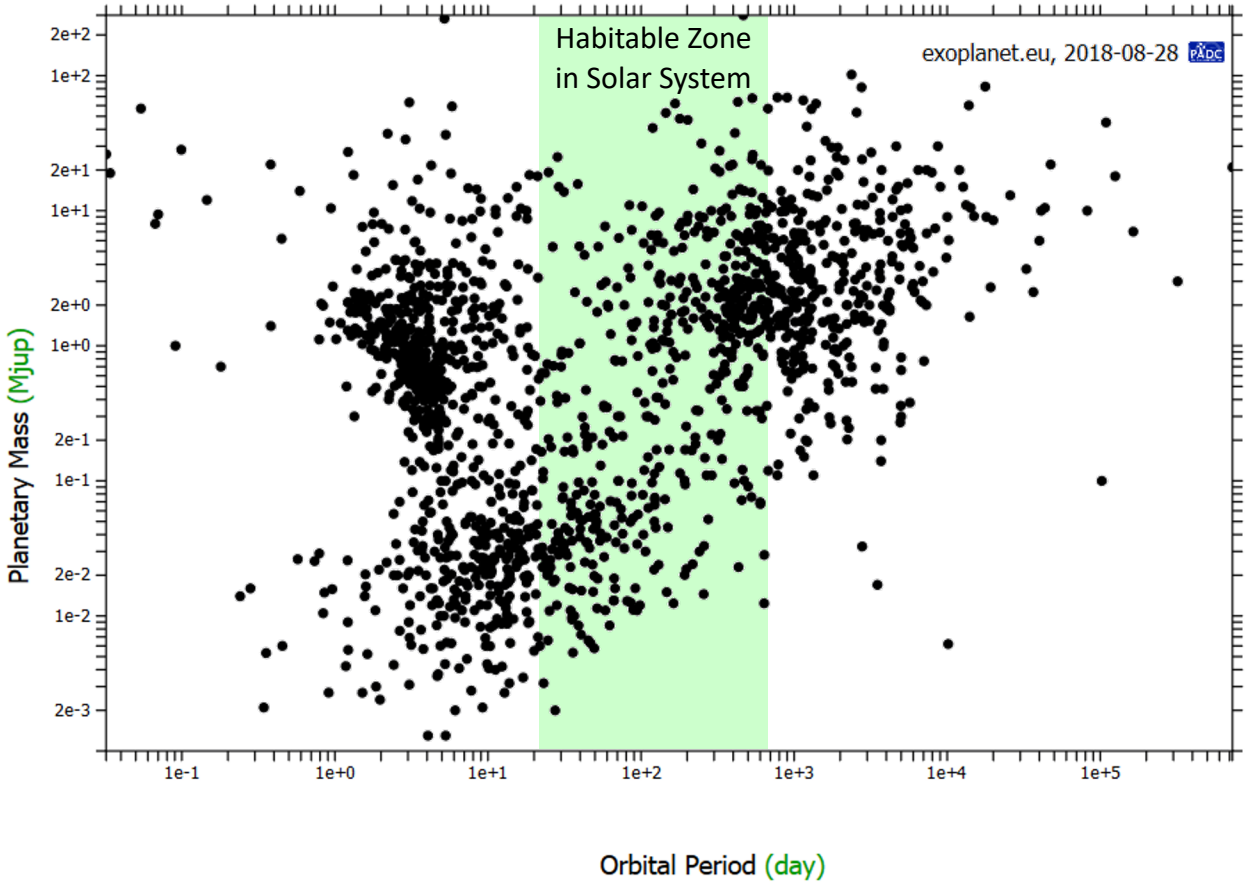


Andrew W. Howard, *Science,* 03 May 2013

Exoplanets with Habitable Temperatures are Very Common

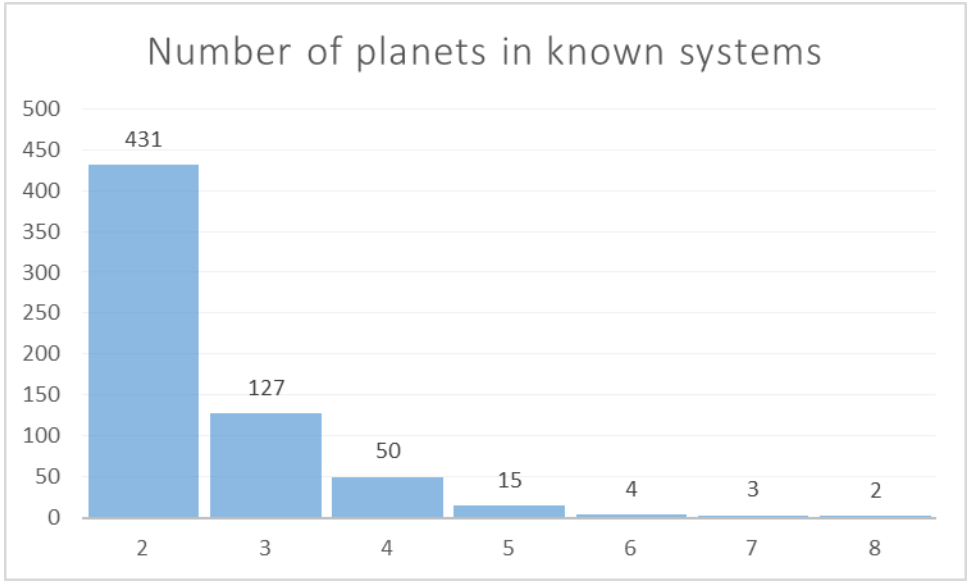
- Habitable = Could have liquid water: not too hot, not too cold
- Liquid water on a solid surface is considered most hospitable to life as we know it → Small rocky planets are more interesting
- All sizes of planets are worth considering
  - Moons of giant exoplanets could be habitable

Potentially Habitable Exoplanets	
Mars-size	1
Earth-size	22
Super-Earth/ Mini-Neptune	32
Total	55



Planetary systems are common

- There are 632 known planetary systems
  - Two or more planets around the same star(s)
- Some have small planets in the habitable zone



How do we find and study planets?

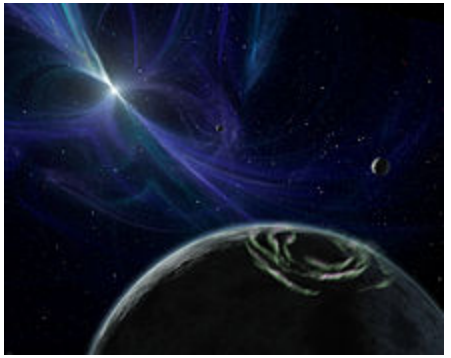
- Several methods have been used, each with their own strengths
  - Dopper Radial Velocity / Timing Variations
  - Transit photometry, spectroscopy
  - Brightness variations over an orbit
  - Microlensing
  - Direct Imaging
  - …and others

- Several of these work from both ground telescopes and space

IMAGES

Doppler Radial Velocity / Timing Variations

- Planets are inferred from their gravitational pull on the host star or other planets
- Earliest detections were by Doppler variations
  - Pulsar timing (1992)
  - 51 Peg – Optical Doppler shift (1995)



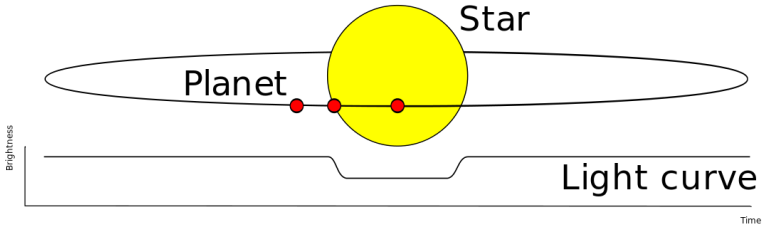
Pulsar planets (Wolszczan & Frail 1992)

- Ground-based optical Doppler radial velocity
- 17.9% of all planets we've discovered

VIDEO

Transit photometry, spectroscopy

- If the planet passes in front of or behind the star, we can see a brief change in their combined brightness
  - A few percent to 10 parts per million, for several hours out of every orbit
  - Staring without blinking is the best strategy
  - Even small ground telescopes work well, but space is more sensitive



Nikola Smolenski - commons.wikimedia.org

- Las Cumbres Observatory and other networks of telescopes can team up to monitor the same stars without interruption
- Space telescopes like Kepler and TESS stare at large patches of sky for days to months without interruption
- 78.2% of all exoplanets we've discovered

Brightness variations over an orbit

- The light from a planet often varies around its orbit, because the side facing the star doesn't always face toward us

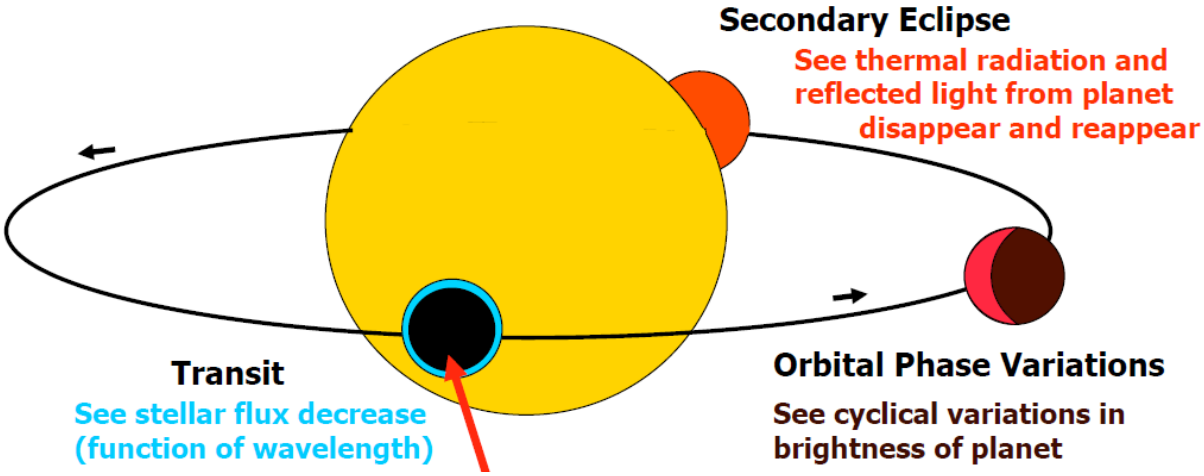
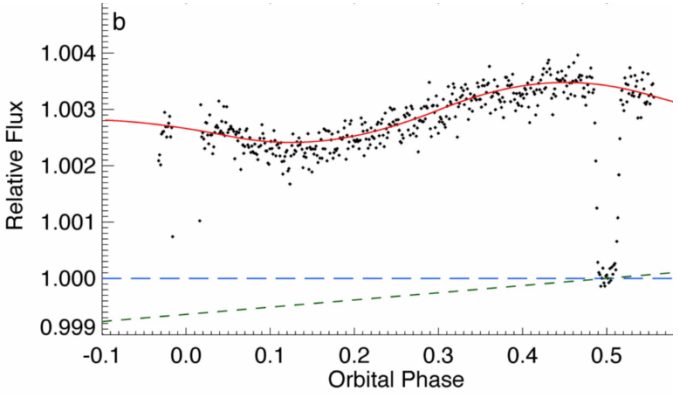
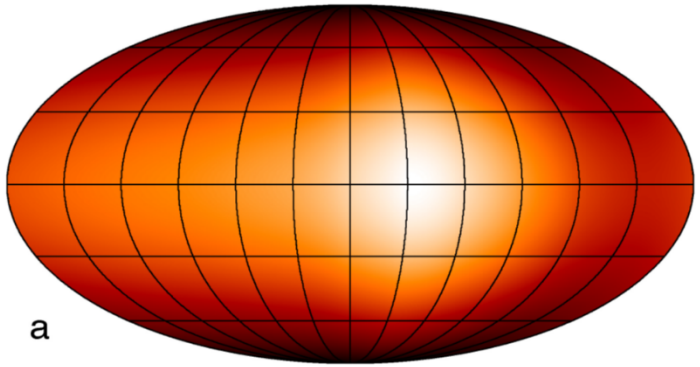


Figure by Knutson

- Some planets are bright enough that their brightness variation is detectable in the total brightness from the star





HD 189733b (Knutson et al., *Nature* 2007

Microlensing

- When two stars line up with Earth, the closer one bends the light of the farther one, and brightens it briefly
  - The adjacent planet adds another blip
- Very sensitive to small planets in more distant orbits
- Relevant efforts
  - MOA collaboration – Microlensing Observations in Astrophysics
    - Nagoya Univ with international participation
    - Using 1.8m telescope in New Zealand
  - OGLE collaboration – Optical Gravitational Lensing Experiment
    - Univ Warsaw with international participation
    - Using 1.3m telescope in Atacama desert, Chile
  - WFIRST microlensing survey
    - A science program on WFIRST (launch in 2025)

Direct imaging

- Block the glare from the exoplanets host star, to reveal the planet
  - Stars are typically 0.1 billion to 10 billion times brighter than planets
  - Planets like ours are typically 0.05 arcsec to 10 arcsec from their stars
    - The width of a human hair at distances between 6 ft and 1/4 mile
- Very difficult to get such strong suppression of glare at such small angles
- Two main techniques
  - Coronagraph – focus the star onto a dot inside the telescope
  - Starshade – block the star before the telescope with a “sun-visor” as big as a baseball diamond
  - Both are technically challenging
- Successful ground-based coronagraphs – GPI, Subaru
- Hubble, JWST, WFIRST coronagraphs

Starshade video

Coronagraph video

What To Watch For

- Kepler data analysis
- TESS - Transiting Exoplanet Survey Satellite (launched in April)
- JWST - James Webb Space Telescope (launch in 2020)
- WFIRST - Wide Field InfraRed Space Telescope (launch in 2025)

Missions into the future